

INTERFEROMETRIC OBSERVATIONS OF V1663 AQUILAE (NOVA AQL 2005)

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ABSTRACT

We have resolved the classical nova V1663 Aql using long-baseline near-IR interferometry covering the period from ~ 5 –18 days after peak brightness. We directly measure the shape and size of the fireball, which we find to be asymmetric. In addition we measure an apparent expansion rate of 0.21 ± 0.03 mas day⁻¹. Assuming a linear expansion model we infer a time of initial outburst approximately 4 days prior to peak brightness. When combined with published spectroscopic expansion velocities our angular expansion rate implies a distance of 8.9 ± 3.6 kpc. This distance measurement is independent of, but consistent with, determinations made using widely available photometric relations for novae.

Subject headings: techniques:interferometry–star:V1663 Aql–novae

1. INTRODUCTION

Novae are violent stellar explosions exceeded in energy output only by γ -ray bursts and supernovae. They are erratic outbursts that occur in systems containing a white dwarf accreting mass from a late-type stellar companion (e.g. Prialnik & Kovetz 2005). When the amount of accreted material on the surface of the white dwarf reaches some critical value a thermonuclear-runaway is ignited, giving rise to the observed nova outburst in which material enriched in heavy elements is ejected into the surrounding medium at high velocities. For certain elements, this ejected material may influence observed abundances in the ISM (Gehrz et al. 1998; Hernanz 2005). Direct observations of the expansion of the nova shell provide an opportunity to accurately determine the distance to the nova. Such observations are usually only possible many months or years after the outburst, when the expanding shell can be resolved (Bode 2002). However, several optical/IR interferometers are now capable of resolving novae and other explosive variables, allowing detailed studies of the initial “fireball”, (Chesneau et al. 2007; Monnier et al. 2006) as well as later stages of development (Lane et al. 2005, 2007).

Nova Aquilae 2005 (ASAS190512+0514.2, V1663 Aql) was discovered on 9 June 2005 by Pojmanski & Oksanen (2005). At the time of discovery the magnitude was $m_V = 11.05$; the source reached $m_V \sim 10.8$ the following day, and declined in brightness thereafter. A possible progenitor near the source coordinates (sep. ~ 4.5 arcseconds) is seen on Palomar Optical Sky Survey plates (USNO-B1.0 0952-00410569, Monet et al. (2003)), with magnitudes $m_R \sim 18.1$ and $m_I \sim 16.45$. Soon after discovery Deneffeld et al. (2005) obtained an optical spectrum with features indicating a heavily red-

dened, peculiar nova. H- α emission lines exhibited P Cygni line profiles and indicated an expansion velocity of 700 ± 150 km s⁻¹ (Deneffeld et al. 2005, confirmed via personal communication), somewhat slow for a classical nova, but not outside the range of observed values. Recently, Poggiani (2006) published spectra and analysis of published light-curves of this nova, deriving a distance in the range 7.3–11.3 kpc, and an expansion velocity of ~ 2000 km s⁻¹.

We have used the Palomar Testbed Interferometer (PTI) to resolve the $2.2\mu\text{m}$ emission from V1663 Aql and measure its apparent angular diameter as a function of time. We are able to follow the expansion starting ~ 9 days after the initial explosion; when combined with radial velocities derived from spectroscopy we are able to infer a distance to, and luminosity of, the object. We compare this result with values inferred by a maximum magnitude-rate of decline (MMRD) relation in the literature (see Poggiani 2006 for a summary).

The Palomar Testbed Interferometer (PTI) was built by NASA/JPL as a testbed for developing ground and space-based interferometry and is located on Palomar Mountain near San Diego, CA (Colavita et al. 1999). It combines starlight from two out of three available 40-cm apertures and measures the resulting interference fringes. The high angular resolution provided by this long-baseline (85-110 m), near infrared ($2.2\mu\text{m}$) interferometer is sufficient to resolve emission on the milli-arcsecond scale.

2. OBSERVATIONS

We observed V1663 Aql on 10 nights between 15 June 2005 and 28 June 2005; on six of those nights we obtained data on two or three interferometric baselines. For a detailed description of the instrument we refer the reader to Colavita et al. (1999). Each nightly observation consisted of one or more 130-second integrations during which the normalized fringe visibility of the science target was measured. The measured fringe visibilities of the science target were calibrated by dividing them by the point-source response of the instrument, determined by interleaving observations of calibration sources (Table 1); the calibration sources were chosen to be single stars, close to the target on the sky and to have angular diameters less than 2 milli-arcseconds, determined by

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Calibrator	V	K	Spectral Type	Ang. Diameter θ_{UD} (mas)	Separation (deg)
HD 176303	5.27	3.93	F8V	0.71 ± 0.03	8.5
HD 188310	4.72	2.17	G9III	1.62 ± 0.08	13
HD 186442	6.56	3.67	K0III	0.92 ± 0.16	11

TABLE 1

RELEVANT PARAMETERS OF THE CALIBRATORS AND CHECK STAR. THE SEPARATION LISTED IS THE ANGULAR DISTANCE FROM THE CALIBRATOR TO V1663 AQL. ALTERNATE CATALOG DESIGNATIONS: HD 176303 = 11 Aql = HR 7172; HD 188310 = 59 Aql = ξ Aql = HR 7595; HD 186442 = BD +09 4233 = SAO 125000.

Epoch (MJD)	u (m)	v (m)	No. Pts.	Cal. Visibility (V^2)
53536.424	-75.3240	-25.0938	1	0.698 ± 0.117
53537.393	-79.8978	-23.7842	8	0.749 ± 0.030
53538.383	-44.1836	66.0275	10	0.718 ± 0.033
53539.346	-81.4086	-21.8080	14	0.672 ± 0.050
53540.392	-79.3017	-24.1591	4	0.610 ± 0.035
53540.333	-51.6711	-88.3761	5	0.567 ± 0.026
53541.395	-78.3316	-24.4178	3	0.568 ± 0.038
53541.339	-48.6701	-88.6301	5	0.484 ± 0.024
53542.396	-77.4187	-24.5759	3	0.538 ± 0.037
53542.320	-53.4276	-88.0947	6	0.534 ± 0.048
53542.458	-59.4251	63.4296	5	0.519 ± 0.074
53543.400	-76.2535	-24.8719	4	0.499 ± 0.029
53543.452	-59.1619	63.5118	5	0.454 ± 0.046
53548.363	-80.2661	-23.8083	5	0.537 ± 0.078
53548.300	-54.5455	-88.0372	5	0.539 ± 0.096
53549.377	-77.8030	-24.5517	2	0.614 ± 0.194
53549.305	-52.5498	-88.2695	4	0.538 ± 0.173

TABLE 2

CALIBRATED FRINGE VISIBILITIES OF V1663 AQL, TOGETHER WITH THE PROJECTED BASELINE COMPONENTS. THE EFFECTIVE WAVELENGTH OF OBSERVATIONS WAS $2.2 \mu\text{m}$. u, v ARE THE COMPONENTS OF THE PROJECTED BASELINE IN METERS. ALL OF THE DATA FROM A GIVEN BASELINE ON A GIVEN NIGHT HAS BEEN AVERAGED.

fitting a black-body to archival broadband photometry of the sources. For further details of the data-reduction process, see Colavita (1999b) and Boden et al. (2000). Calibrated fringe visibilities are listed in Table 2; though given as averages, the fits to the models were done using the individual data points, without averaging on a nightly basis. Note that HD 188310 has been claimed to be a binary with a separation of 0.09 ± 0.01 arcseconds (Scardia et al. 2000). However, this claim is based on a single observational epoch obtained under poor observing conditions, and has to our knowledge not been confirmed by any other group. We do not see any indications of binarity in our data; the fringe visibilities of HD 188310 are stable to 2.5% when calibrated using HD 176303. In addition, we reduce the V1663 Aql data both with and without using HD 188310 as a calibrator and find the results to be fully self-consistent. We include HD 188310 as a calibrator in the results shown here as it was the only calibrator available on the last night of observations.

PTI is equipped with a low-resolution spectrometer which provides fringe visibility measurements and photon count rates in five spectral channels across the K band. In addition to the fringe visibilities measured in each channel (referred to as “narrow-band” visibilities), we compute a wide-band average visibility as the photon-

weighted average of the five spectral channels. Using photon count rates from PTI and K-band magnitudes for the calibrator sources provided by 2MASS (Beichman et al. 1998), we also derive a K-band apparent magnitude of V1663 Aql. It should be remembered that PTI was not designed for high-precision photometry, and hence the K-magnitudes, while useful, should be treated with some caution.

3. MODELS & RESULTS

3.1. Interferometric Data

The theoretical relation between source brightness distribution and fringe visibility is given by the van Cittert-Zernike theorem (Thompson et al. 2001). For a uniform intensity disk model the normalized fringe visibility (squared) can be related to the apparent angular diameter using

$$V^2 = \left(\frac{2 J_1(\pi B \theta_{UD} / \lambda)}{\pi B \theta_{UD} / \lambda} \right)^2 \quad (1)$$

where J_1 is the first-order Bessel function, B is the projected aperture separation and given by $B = \sqrt{u^2 + v^2}$ where u, v are two orthogonal components of the projected baseline, θ_{UD} is the apparent angular diameter of the star in the uniform-disk model, and λ is the wavelength of the observation.

We obtain an initial characterization of the data using a circularly symmetric uniform-disk model fit to data from a single baseline on a nightly basis (Fig. 1). This indicates that the apparent source morphology was initially expanding, but that the apparent expansion reversed sometime between MJD 53545 and MJD 53548. The data also clearly indicate that while the North-West and South-West data produce consistent angular diameters, the North-South data indicates both a smaller apparent diameter and a less smooth expansion. Clearly, a more sophisticated morphological model is required.

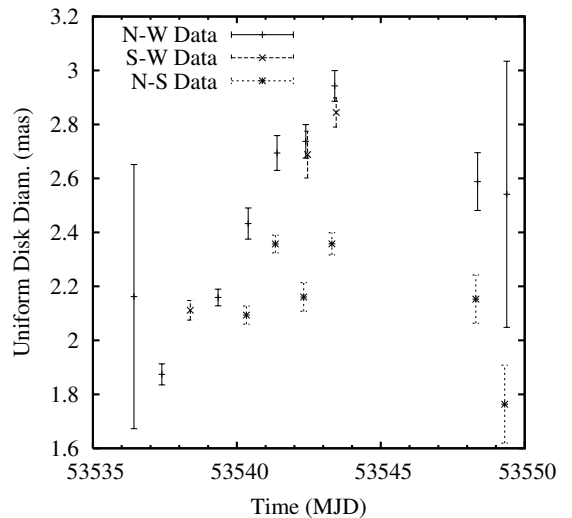


FIG. 1.— The apparent angular diameter of the V1663 Aql source, as a function of time, assuming a uniform (circular) disk model. Each symbol represents a fit to data from a single baseline. Although the data are all consistent with an expansion, the disagreement between various baselines indicates the need for a more complex morphological model.

The availability of data taken with multiple baselines

with different position angles allows us to distinguish between a circularly symmetric source and elliptical disk models. For the asymmetric cases we fit for three parameters: size (θ), inclination angle (ϕ), and position angle (ψ). Inclination is defined such that a face-on disk has $\phi = 0$ and ψ is measured east of north. Following Eisner et al. (2003), we include ϕ and ψ in our models of the brightness distribution via a simple coordinate transformation:

$$u' = u \sin \psi + v \cos \psi \quad (2)$$

$$v' = \cos \phi (v \sin \psi - u \cos \psi) \quad (3)$$

Substitution of (u', v') for (u, v) in the expressions above yields models with inclination effects included. Note that the “inclination” is not tied to a true disk-like morphology; the source can well be (and in this particular case probably is) an ellipsoid, in which case the major axis of the ellipsoid is θ and the minor axis is given by $\theta \cos(\phi)$. We perform least-squares fits of uniform and inclined disk (or equivalently ellipsoidal) models to the measured fringe visibilities.

As is apparent from Fig. 2 the data on nights with more than one available baseline are not well matched by a simple uniform disk model; in effect the visibility in the North-South baseline is too high (and the corresponding uniform-disk diameter too small) to be consistent with the North-West and South-West baselines. Typical goodness-of-fit parameters are $\chi_r^2 \sim 5$. However, it is possible to fit the data using an inclined disk-model (Table 3). While the angular size scale changes from night to night, the consistency of the inclination and position angles of the fits lend credence to the idea that we are observing an expanding, asymmetric source.

We examine the possibility of systematic errors mimicking the effect of non disk-like emission using the following test: we use HD 186442 as a “check star” by making observations of it interleaved with observations of our calibrators and V1663 Aql. Such observations were made on three nights, and on two of those nights we observed the check star with all three available interferometric baselines. We calibrate the check star data using the same procedure as applied to V1663 Aql, and fit a uniform-disk model to the calibrated nightly data. We find that the best-fit uniform disk diameter is 0.83 ± 0.05 milli-arcseconds with a goodness-of-fit parameter (χ_r) of 0.80 for 16 130-second data points, and a mean scatter in the visibilities about the best-fit model of 2.9%, fully comparable with typical point source observations using PTI.

Given the reasonable stability of the position angle and inclination (or equivalently, aspect ratio) parameters, we re-fit the data from all the nights, holding these two parameters fixed at the average values from Table 3 (excluding the last two points where the fits are effectively indeterminate), while letting the diameter vary on a nightly basis. The resulting best-fit diameters are given in Table 4 and shown in Figure 3. A simple linear expansion model fit to the disk sizes indicates an expansion rate of 0.21 ± 0.03 milli-arcseconds/day, beginning on MJD 53527.4 \pm 1.9.

3.2. Narrow-band Interferometric Data

In addition to the wide-band fringe visibilities, we can compute the best-fit disk diameters for data from each spectral channel separately; results from three nights are

show in Fig. 4. The lack of significant variation in apparent angular diameter with wavelength supports our assumption that the observed visible emission lines are originating from the same region as the K-band emission seen by PTI, at least during the first few weeks of the expansion.

3.3. Photometry

We derive the approximate K-band magnitude of V1663 Aql using photon fluxes measured by PTI; the results are shown in Fig. 5. We have also collected B and V-band photometry published from VSNET⁷ and IAU circulars. We fit a linear trend to the data in order to derive the rate of declines in the K and V bands; we find that the PTI K-band photometry implies $\dot{m}_K = 0.13 \pm 0.01 \text{ mag day}^{-1}$, and the compiled V-band photometry gives $\dot{m}_V = 0.126 \pm 0.004 \text{ mag day}^{-1}$. The V-band data indicates a time to decline 2 magnitudes from maximum (t_2) of 15.9 ± 0.5 days, and a 3-magnitude decline $t_3 = 23.8 \pm 0.8$ days. We also fit a low-order polynomial function to the B- and V-band photometry, allowing us to find an approximate $B-V$ color for $t = t_2$ of 1.11. Based on the work by van den Bergh & Younger (1987) the intrinsic $B-V$ color of novae two magnitudes below maximum light is -0.02 ± 0.04 , and hence we infer $E(B-V) = 1.1$. The corresponding V-band extinction $A_V \sim 3.4$ mag.

We use the MMRD relation from della Valle & Livio (1995) and our value of t_2 to derive $M_V = -8.31$ for V1663 Aql. Adopting a peak value of $m_{V,max} = 10.8$ we would predict a distance of ~ 13.8 kpc.

4. DISCUSSION

Using our interferometrically measured angular diameters it is possible to constrain three important parameters of this system: the fireball shape, the time of initial expansion, and the distance to the system. However, we note that we are using relatively simplistic models, and our interpretations are therefore limited and subject to a systematic uncertainty that is difficult to quantify. Nonetheless, the measured fringe visibility and the way it changes with time and baseline strongly imply that the source is expanding and likely asymmetric.

First, we measure a non-zero asymmetry in the expanding fireball as early as ten days after the initial outburst; this would tend to indicate that the source of the asymmetry is inherent to the explosion mechanism and not the result of interactions with the interstellar or circumstellar medium. As discussed in Bode (2002) there is an apparent correlation between nova speed class and apparent asymmetry; our measured asymmetry (major/minor axial ratio = 1.44, for $t_3 \sim 24$ d) is larger than what would be expected from that relation (1.0–1.1).

Second, we can extrapolate backward in time to find the time of the initial explosion; we find that it occurred around MJD 53527.4 \pm 1.9. Comparing this with the time of maximum V-band luminosity (MJD 53531.7 \pm 0.1; Poggiani 2006) we find a delay of $\sim 4 \pm 2$ days between the onset of expansion and the maximum observed luminosity. In this context we note the somewhat odd V-band point from June 3 ($m_V = 14$) reported in Pojmanski & Oksanen (2005); this is probably not the

⁷ <http://www.kusastro.kyoto-u.ac.jp/vsnet/>

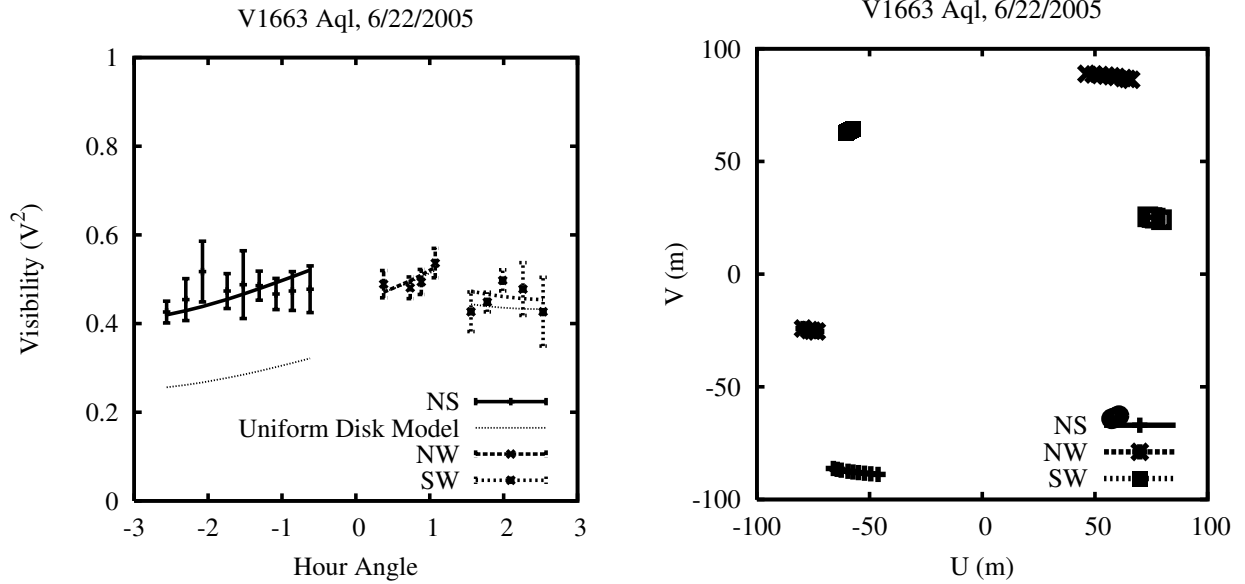


FIG. 2.— (left) The measured fringe visibility of V1663 Aql as a function of hour angle during the night of 22 June 2005. Although PTI can only use one baseline at a time, during the night two changeovers were performed, yielding data on all three baselines within a relatively short period of time. An inclined-disk model was fit to the data (shown as thick lines), yielding a good fit. The fit parameters are given in Table 3. A corresponding uniform-disk fit (thin lines) is shown for comparison; while it can match the N-W and S-W data it significantly under-predicts the N-S baseline visibilities. (right) The uv -plane coverage (i.e. the projected baselines) of the observations.

Date	χ_r	Size (mas)	ψ (deg)	ϕ (deg)	Baselines
19 June 2005	0.4	3.1 ± 0.5	129.5 ± 6.6	49.2 ± 8.3	NS,NW
20 June 2005	0.8	3.3 ± 0.5	127.7 ± 7.9	46.0 ± 9.2	NS,NW
21 June 2005	0.5	2.9 ± 0.05	103.8 ± 2.9	44.8 ± 2.0	NS,NW,SW
22 June 2005	0.6	3.1 ± 0.05	101.6 ± 2.1	45.11 ± 2.0	NS,NW,SW
27 June 2005	0.4	3.2 ± 1.0	127.1 ± 19	48.8 ± 18	NS,NW
28 June 2005	4.4	2.8 ± 1.7	80.7 ± 161	89.2 ± 360	NS,NW

TABLE 3

INCLINED-DISK MODEL FITS TO DATA FROM A GIVEN MULTI-BASELINE NIGHT. NS = NORTH-SOUTH, NW = NORTH-WEST AND SW SOUTH-WEST BASELINES, RESPECTIVELY

Date	MJD	Size (mas)	χ_r
16 June 2005	53537.393	2.13 ± 0.03	0.7
17 June 2005	53538.383	2.23 ± 0.03	0.6
18 June 2005	53539.346	2.44 ± 0.03	0.9
19 June 2005	53540.359	2.92 ± 0.04	1.3
20 June 2005	53541.36	3.30 ± 0.06	2.3
21 June 2005	53542.385	3.03 ± 0.05	1.2
22 June 2005	53543.366	3.21 ± 0.06	2.6
27 June 2005	53548.325	3.01 ± 0.05	0.4
28 June 2005	53549.329	2.57 ± 0.35	3.3

TABLE 4

THE BEST-FIT MAJOR-AXIS ANGULAR SIZES OF INCLINED-DISK MODELS FIT TO THE DATA ON A NIGHTLY BASIS. THE INCLINATION OF THE DISKS WAS FIXED AT 46 DEGREES, AND THE POSITION ANGLE WAS HELD AT 115 DEGREES, CORRESPONDING TO THE AVERAGE VALUES DETERMINED FROM THE BEST FITS IN TABLE 3.

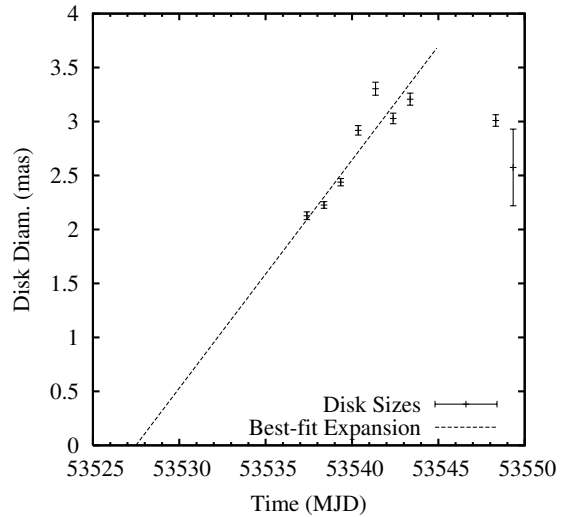


FIG. 3.— The best-fit inclined disk diameter as a function of time, together with a best-fit linear expansion model. The expansion appears to stop sometime after MJD 53545; the subsequent points have been left out of the fit.

pre-outburst magnitude of the nova. However, this point would then indicate the the outburst began sometime before 3 June, i.e. even earlier than our T_0 . We have no other indications of a pre-maximum halt in this nova and note that such phenomena are usually associated with slow novae. On the other hand, Kato et al. (2002) have observed a long pre-maximum halt in the rapidly evolving nova V463 Sct, indicating that such expecta-

tions cannot be absolute.

Third, we can use our measured expansion rate of $0.21 \pm 0.03 \text{ mas day}^{-1}$ together with spectroscopically

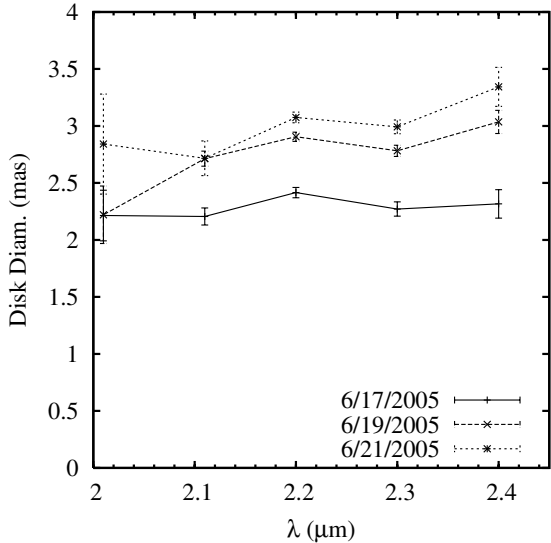


FIG. 4.— The best-fit inclined disk diameter as a function of wavelength, for data from three nights. The inclination and position angles were held fixed at the average best-fit values from Table 3

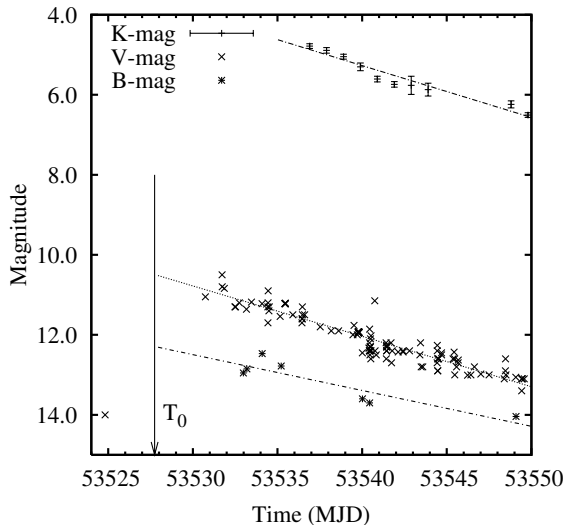


FIG. 5.— Measured B-, V- and K-magnitudes of V1663 aql following the nova outburst. K magnitudes were measured by PTI, while B and V magnitudes were collected from VSNET and IAU circulars. The best-fit linear magnitude trends are also shown, together with the time of initial expansion T_0 determined from fitting to the measured diameters.

determined expansion speeds to find a geometric distance to this nova, independent of any photometric biases. Unfortunately there appears to be little consensus as to the spectroscopically determined expansion velocity, with available estimates differing by a factor of three. Poggiani (2006) measured the $H\alpha$ line on 31 July 2005 and finds a Half-Width at Zero Intensity (HWZI) $\sim 2000 \text{ km s}^{-1}$, indicating an expansion velocity in that range, while the O I 8446 line from the same paper appears more consistent with a HWZI of $\sim 1500 \text{ km s}^{-1}$. On the other hand, Dennefeld et al. (2005) find an expansion rate of 700 km s^{-1} from spectroscopy obtained on 11 June 2005, while Puetter et al. (2005) find a Full-Width at Zero Intensity $\sim 2600 \text{ km s}^{-1}$ from spectroscopy obtained on 14 Nov 2005. We adopt an intermediate value of $1375 \pm 500 \text{ km s}^{-1}$, being the average and standard de-

viation of the four values listed above. In this context we note that the expected expansion rate for a nova with $t_3 = 23.8$ days is $\sim 1000 \text{ km s}^{-1}$ (McLaughlin 1960).

A second difficulty, explained by Wade et al. (2000), is that for a non-spherical nova shell the unknown orientation of the shell in the plane of the sky biases any distance determination that does not account for this inclination effect, and in fact the proper inclination can only be determined with spatially resolved spectroscopy. In our case, we measure an ellipse with an apparent minor/major axis ratio of $\cos(\theta) = 0.69$, and do not have access to any information that would unambiguously constrain the inclination of the nova shell; we therefore use the estimator recommended by Wade et al. (2000), viz. the arithmetic mean of the apparent major and minor axis expansion rates. This estimator will on average yield a result within a few percent of the true distance as long the orientation of the nova shell isn't close to 0 or 90 degrees. We find a distance to this nova of 8.9 ± 3.6 kpc. This is consistent with the range derived by Poggiani (2006), based on a number of photometric MMRD relations available in the literature (7.3–11.3 kpc), but marginally inconsistent with the value we derive in Section 3.3. We caution, however, that the expansion rate may in fact change with time; this could explain the range of measured rates, as well as bias our result.

Finally, an important feature in our data is that the apparent expansion ceased sometime after MJD 53545 (day 18). We note that behavior is similar to what was seen in RS Oph (Lane et al. 2007), where the apparent expansion appeared to reverse around day 20. It is possible that the apparent reversal is not due to the transition from optically thick to optically thin emission from the expanding fireball (Gehrz 1988), but rather that the wind mass-loss rate (and hence effective optical depth of the source material) is changing. However, the details of this process are not easily modeled and we will explore this further in subsequent papers.

5. CONCLUSION

We have used long-baseline near-IR interferometry to resolve the classical nova V1663 Aql, starting ~ 9 days after outburst. We measure an apparent expansion rate of $0.21 \pm 0.03 \text{ mas day}^{-1}$, which can be combined with previously determined expansion velocities to produce a distance estimate to the nova of 8.9 ± 3.6 kpc; the precision is limited by the precision of the available spectroscopic radial velocities. Such a large distance is consistent with the large reddening ($E(B - V) \sim 1.1$) determined from photometry, as well as with distances found from MMRD relations. This represents only the third time a nova has been resolved using optical/IR interferometry, the previous cases being Nova V1974 Cyg 1992 (Quirrenbach et al. 1993) and more recently RS Oph (Monnier et al. 2006; Lane et al. 2007). We anticipate that further instrumental improvements, in particular high spectral resolution interferometry such as that recently deployed on the Keck Interferometer (Eisner et al. 2007), may break the inclination degeneracy and thus yield very precise expansion distances to these interesting objects.

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are made possible through the efforts of the PTI Collaboration, which we gratefully acknowledge. This research has made use of services from the Michelson Science Center, California Institute of Technology, <http://msc.caltech.edu>. Part of the work described in this paper was performed at the Jet Propulsion Laboratory under contract with the National Aeronautics and Space Administration. This research has made use

of the Simbad database, operated at CDS, Strasbourg, France, and of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the NASA and the NSF. MWM is grateful for the support of a Townes Fellowship.

REFERENCES

- Beichman, C. A., Chester, T. J., Skrutskie, M., Low, F. J., & Gillett, F. 1998, *PASP*, 110, 480
- Bode, M. F. 2002, *Classical Nova Explosions*, 637, 497
- Boden, A., Creech-Eakman, M., Queloz, D., 2000, *ApJ*, 536, 880-890.
- Chesneau, O., et al. 2007, *A&A*, 464, 119
- Colavita, M. M., et al. 1999, *ApJ*, 510, 505.
- Colavita, M. M., 1999, *PASP*, 111, 111.
- Dennefeld, M., Ricquebourg, F., & Damerdjy, Y. 2005, *IAU Circ.*, 8544, 1
- della Valle, M., & Livio, M. 1995, *ApJ*, 452, 704
- Eisner, J. A., Lane, B. F., Akeson, R. L., Hillenbrand, L. A., & Sargent, A. I. 2003, *ApJ*, 588, 360
- Eisner, J. A., et al. 2007, *ApJ*, 654, L77
- Gehrz, R. D., Truran, J. W., Williams, R. E., & Starrfield, S. 1998, *PASP*, 110, 3
- Gehrz, R. D. 1988, *ARA&A*, 26, 377
- Hernanz, M. 2005, *Astronomical Society of the Pacific Conference Series*, 330, 265
- Kato, T., Uemura, M., Haseda, K., Yamaoka, H., Takamizawa, K., Fujii, M., & Kiyota, S. 2002, *PASJ*, 54, 1009
- Lane, B. F., Retter, A., Thompson, R. R., & Eisner, J. A. 2005, *ApJ*, 622, L137
- Lane, B. F., et al. 2007, *ApJ*, 658, 520
- Monet, D. G., et al. 2003, *AJ*, 125, 984
- Monnier, J. D., et al. 2006, *ApJ*, 647, L127
- Ney, E. P., Hatfield, B. F., 1980, *AJ*, 85, 1292.
- Prialnik, D., & Kovetz, A. 2005, *AIP Conf. Proc.* 797: *Interacting Binaries: Accretion, Evolution, and Outcomes*, 797, 319
- Poggiani, R. 2006, *Astronomische Nachrichten*, 327, 895
- Pojmanski, G., & Oksanen, A. 2005, *IAU Circ.*, 8540, 1
- Puetter, R. C., Rudy, R. J., Lynch, D. K., Mazuk, S., Venturini, C. C., Perry, R. B., & Walp, B. 2005, *IAU Circ.*, 8640, 2
- Thompson, A. R., Moran, J. M., Swenson, G. W., 2001, *Interferometry and Synthesis in radio Astronomy*, (2nd ed; New York, NY : Wiley)
- Quirrenbach, A., Elias, N. M., Mozurkewich, D., Armstrong, J. T., Buscher, D. F., & Hummel, C. A. 1993, *AJ*, 106, 1118
- Scardia, M., Prieur, J.-L., Aristidi, E., & Koechlin, L. 2000, *ApJS*, 131, 561
- van den Bergh, S., & Younger, P. F. 1987, *A&AS*, 70, 125
- Wade, R. A., Harlow, J. J. B., & Ciardullo, R. 2000, *PASP*, 112, 614